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"Improvements for Nuclear Quadrupole Resonance Measurements"

Field of the Invention

This invention relates to improvements in the measurement of nuclear quadrupole

5   resonance (NQR), which has particular, although not exclusive, utility in the detection of explosives and narcotics located within mail, airport luggage and other packages using NQR. More specifically the invention relates to overcoming one or more extrinsic problems associated with the capacity to excite and/or detect NQR in a substance containing quadrupole nuclei.

10 Throughout the specification, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

Background Art

15 The following discussion of the background art is intended to facilitate an understanding of the present invention only. It should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to is or was part of the common general knowledge as at the priority date of the application.

20 NQR has been proposed as an alternative technology for the detection of explosives, narcotics and other illicit substances containing quadrupole nuclei responsive to the NQR phenomenon. Whilst NQR detection technology in theory may be used to detect explosives in items at airports, mail centres and entry points to important buildings such as courthouses etc, in practice, great difficulty

25 has been encountered in designing and producing an NQR scanner that is practicable and reliable to operate in such environments.

An NQR scanner device theoretically brings an item to be scanned, such as luggage, to stop within a coil or near a coil or coils. The computer in control of the device directs the transmitter to irradiate the item being scanned with a burst of radiofrequency (RF) waves, which excite an NQR substance within the item being
5   scanned. After a short period of dead time the receiver detects any very small voltage induced on the coil by relaxing quadrupolar nuclei. The computer then receives and transforms this signal and determines whether this signal exceeds a predetermined threshold level. If the signal does exceed the threshold level an alarm is signalled to the operator.

10   It has been found, however, that the entire process is dependent upon the physical characteristics of the item being scanned and the surrounding environment. Certain characteristics of the scan item affect the detection capability and the false alarm rate.

One of the major problems that has so far restricted the use of NQR technology is
15   the fact that the NQR frequencies of different NQR substances drift with temperature. The amount of drift is not large (427Hz/°C for the 5.2MHz line of RDX), but is enough to cause problems in measuring small hard to find signals as would be required in a practical NQR scanner. The main problem is that if the temperature of the item is unknown, then the resonant frequency of the NQR
20   substance will also be unknown. Consequently, the item may be irradiated at the incorrect frequency resulting in a missed detection.

To overcome this problem the range of frequencies irradiated can be enlarged by using a lower transmit Q factor, however this would still result in a possible missed detection because a high receive Q factor is usually required to detect such small
25   NQR signals.

An alternative method is to selectively irradiate small sections of the frequency spectrum sequentially so the probability of detection increases. By using this method a range of frequencies corresponding to a range of temperatures can be irradiated maximising the probability of detection. For instance, in an airport
30   scenario for detecting an explosive having NQR nuclei, it may be expected that

the range of temperatures encountered may be 0-40°C. Hence by arranging the system to irradiate all frequencies that correspond to that temperature range, the explosive should be detected.

One of the problems with the above method is the fact that it requires the use of
5   sequential pulse sequences, each of which consume valuable time. During airport scanning of baggage, the time allowed for scanning a bag approximately ranges from 6-20 seconds. By scanning to cover a range of temperature of say 10-35°C, as many as 3 or 4 pulse sequences have to be applied so that the explosive is properly irradiated. This method results in an unacceptably long delay, which is
10   unacceptable to the machine operator and passengers alike.

Furthermore, when irradiating the bag with two separate pulse sequences, there is a strong possibility that the explosive will be partially excited on the first sequence, resulting in a weak signal which is not detected, and then partially excited again on the second sequence, which is also not detected, resulting in a
15   missed detection.

Another possibility is to interleave the pulse sequences such that each successive pulse group has one of the 3 or 4 frequencies required. However, the time taken to achieve the same signal sensitivity is still 3 or 4 times longer as compared to a single pulse sequence.

20   In the process of scanning objects and relying upon RF frequencies for signal detection, NQR scanners invariably encounter the problem of RF interference. The RF interference can be external or internal to the machine. One form of internal interference can emanate from the item being scanned. Items such as mobile phones, toys, video cameras, watches etc all emit RF noise resulting in
25   difficulty in the detection of weak NQR RF signals. Pulse sequences that have been used to overcome magnetoacoustic ringing, may partially counteract this problem, however these techniques cannot fully remove this phenomenon.

A further problem is that the detection of illicit substances containing NQR nuclei encased within metal objects using conventional NQR techniques is difficult. The

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RF waves generated by an NQR scanner device are generally unable to penetrate metal surfaces due to the eddy current effect. This means that in scanning airport luggage for explosives, it may be possible to pass an explosive in a bag through an NQR scanner and it not be detected by the scanner. This

5   problem makes current NQR scanners deficient in their capability, and is one of the principal reasons as to why no commercially viable NQR scanners have appeared in the market.

Disclosure of the Invention

It is an object of the present invention to improve the excitation and detection

10   capability of NQR within items containing quadrupole nuclei responsive to the NQR phenomenon, and which may be scanned for such.

In accordance with a first aspect of the present invention there is provided an apparatus for exciting and detecting NQR in a substance containing quadrupole nuclei responsive to the NQR phenomenon, comprising:

15   a probe for irradiating an item that may contain a substance with RF waves to excite NQR in quadrupole nuclei within the substance and for receiving an NQR signal emitted in response thereto;

a transmitting means for producing and transmitting an RF pulse to the probe to create said RF waves;

20   a receiving means to receive and treat a received signal from said probe for subsequent processing and detection of a said NQR signal therein;

sensing means for sensing an extraneous parameter that may influence the detection of the NQR signal from the item to be scanned; and

a computer for processing the treated received signal to identify a said NQR

25   signal therein and to control the transmitting means and the receiving means in

response to said processing means and said sensing means to optimise the excitation and detection of the NQR signal.

It is an object of a preferred aspect of the invention to provide for the improvement in the excitation and detection of NQR by having regard to the temperature effect

5   problem as described in relation to the background art.

This preferred object may be achieved by using one or more temperature probes as the sensing means for measuring the temperature. These probes either sense the ambient temperature or the scan item temperature and are used to determine at which frequency the sample should be irradiated.

10   Preferably, said control means is adapted to direct the transmitting means and the probe to irradiate the item at a range of NQR frequencies that lie close to the NQR frequency of the substance containing quadrupole nuclei to be detected, as adjusted in accordance with the temperature measured by said temperature probe.

15   Preferably, the measured temperature is the ambient room temperature.

Preferably, the measured temperature is the external building temperature.

Preferably, the measured temperature is the external temperature of the item to be scanned.

Preferably, the temperature measured is the internal temperature of the item to be

20   scanned.

Preferably, the measured temperature is some combination of the ambient room temperature, the external building temperature, the external item temperature or the internal item temperature.

Preferably, a thermal image of the item is used to determine its temperature and

25   detect excessively hot or cold scan items.

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Preferably, the temperature measured originates from a probe tag attached to the item.

Preferably, the apparatus includes an RF probe to monitor any RF emissions from the item to be scanned prior to it being scanned.

5   Preferably, the apparatus includes sensors to determine the height and length of a scanned item prior to it being scanned.

It is an object of another preferred aspect of the present invention to provide for the improvement in the detection of NQR by overcoming or at least mitigating the problem of interference.

10   This preferred object may be achieved by using an RF probe as the sensing means to monitor RF emissions from the item to be scanned before it is actually scanned. This RF probe is used to sense if the RF emissions exceed a prescribed threshold and if so, indicate that the scan item is not appropriate for NQR detection.

15   It is preferred that the RF device is able to detect RF emissions from a sample and send signals representative thereof to the processing means, said processing means being able to monitor the signals and determine if the RF emissions from an item containing a sample exceed a prescribed threshold level, and said control means providing an alarm signal indicating that the item is not appropriate for
20   NQR detection in response to said processing means determining that the RF emissions exceed said prescribed threshold level.

It is an object of another preferred aspect of this invention to provide for the improvement in the detection of NQR by the detection of metal objects contained within items to be scanned.

25   This preferred object may be achieved by using an RF antenna as the sensing means that may be excited with pulses of RF energy and to irradiate an item to be scanned. Preferably, the RF antenna can allow a return signal to be measured

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and transformed into frequency space after a period of dead time to indicate whether there is a significant amount of metal present.

Accordingly, it is preferred that the control means be adapted to excite the antenna with pulses of RF energy that is able to irradiate a sample and receive
5   return signals after a period of dead time, the NQR device having processing means to measure and transform the return signals into frequency space, and if the signal detected at the transmit frequency exceeds a predetermined threshold, signal the presence of a significant amount of metal.

In accordance with a further aspect of the invention, there is provided a method
10   for exciting and detecting NQR in a substance containing quadrupole nuclei responsive to the NQR phenomenon.

Brief Description of the Drawings

The invention will be better understood in the light of the following description of several specific embodiments thereof. The description is made with reference to
15   the accompanying drawings, wherein:

Fig.1: shows a block diagram of an NQR scanner device in accordance with the various embodiments;

Fig.2: is a schematic plan view of the NQR scanner device of Fig 1, showing the relative location of optical or infrared scanners in accordance
20   with the seventh embodiment;

Fig.3 is a flowchart of the decision making process for detection of RF noise emanating from the scan item in accordance with the second embodiment;

Fig.4: is a flowchart of the decision making process for the pulse induction
25   detection of metal objects within a scan item, in accordance with the third embodiment;

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Fig.5: is a flowchart of the decision making process for the alternative embodiment of the induction balance detection of metal objects within a scan item, also in accordance with the third embodiment;

Fig.6: is a flowchart of the decision making process for the the pulse induction metal imaging of metal objects within a scan item, in accordance with the fourth embodiment;

Fig.7: is a flowchart of the decision process for induction balance metal detection of metal objects within a scan item in accordance with a variation of the fourth embodiment;

Fig.8 is a flow chart showing the decision making process for the X-ray detection of shielded objects in accordance with a fifth embodiment;

Fig.9: is a flow chart showing the decision making process for the detection of aluminium shields by microwave and X-ray imaging, in accordance with an alternative arrangement of the fifth embodiment; and

Fig.10: is a diagram showing the detection of shielded objects by a metal detecting 1D coil array, in accordance with another alternative of the fourth embodiment;

Fig.11a is a graph showing the relative effect of an item containing metal on the Q and frequency as the item is moved into the NQR scanning device; and

Fig.11b is another graph showing the use of subtraction in accordance with the sixth embodiment; and

Fig.12 is a flow chart showing the decision making process for detecting aluminium shielding of an object in accordance with an alternative arrangement of the sixth embodiment.

Best Model(s) for Carrying Out the Invention...

The best mode for carrying out the invention will now be described with reference to an apparatus for scanning and detecting illicit substances using the NQR phenomenon, comprising an NQR scanner device and various sensing means, the main components of various embodiments of the apparatus being shown in

5   block diagram form in Figures 1 and 2 of the drawings.

Referring to Figures 1 and 2, the sensing means comprises one or more temperature probes 13, RF antennas 17, metal detectors 18, metal imagers 19, temperature tags 20 and optical or infrared scanners 22 and 23, or any one or combination of these, electrically attached either directly or wirelessly to an NQR

10   scanner device 16 that generally comprises a transmitter unit 10, a receiver unit 11, a computer 12 and a coil 15. The NQR device 16 scans airport luggage, postal items etc. searching for illicit substances.

As previously mentioned, one of the problems associated with using the prior art method of scanning a nuclear quadrupole substance with multiple pulse

15   sequences at differing transmit frequencies to cover a large temperature range is that this causes a large time delay.

This process can be performed more efficiently by adopting the apparatus of the best mode with one or more temperature probes for sensing the ambient temperature and irradiating the item to be scanned with a range of frequencies

20   close to the NQR frequency of the substance containing quadrupole nuclei to be detected. This frequency is adjusted according to the ambient temperature that is sensed by the temperature probes. Thus one of the features of the best mode for carrying out the invention is that the NQR scanner device 16 only need be designed to transmit one pulse sequence at one frequency for detecting a

25   particular substance and thus save valuable time, leading to an increased throughput of items that may be scanned for the detection of illicit substances.

The first specific embodiment of the invention is directed towards an apparatus including the NQR scanner device 16, and a temperature probe or probes 13 for sensing the ambient room temperature prior to scanning an item 14 of interest,

and then scanning the item with the NQR device, compensating for the temperature of the item.

The range of frequencies at which the NQR device 16 scans the item 14 are selected to lie close to the frequency which mathematically corresponds to the
5   temperature or temperatures measured by the probe or probes 13. If multiple probes 13 are used then some mathematical combination is used to calculate the best temperature, such as the average. The computer 12 in the present embodiment is designed to take the temperature measured by the probe or probes 13 and compute the corresponding frequency via a look up table or direct
10   calculation. For instance, the RDX 5.2MHz NQR line drifts approximately at a rate of 427.4Hz/°C close to room temperature. Hence after measuring the temperature the computer operates in accordance with a prescribed algorithm to input the resultant number into the following equation:

$$\text{Frequency} = 0.4274 \times \text{Temperature} + 5202 ; \qquad\qquad (1)$$

15   where: Temperature is in °C and the Frequency is in kHz.

Equation 1 produces a frequency at which to scan the item. The computer 12 is then programmed to direct the transmitter 10 to send pulses to the coil 15 which irradiates the item 14 at a range of frequencies close to this value.

Pulses at these frequencies are transmitted by the transmitter unit 10 to the coil
20   15 to excite the NQR substance, if present, within the item, the quadrupole nuclei creating a small RF magnetic field which induces a small voltage on the coil 15 that is measured by the receiver unit 11 and sent to the computer 12, resulting in a detection. This detection is accomplished at a much faster rate as compared to the prior art method of irradiating the substances with 3 or 4 pulse sequences at
25   different frequencies to cover a large temperature range.

In a variation of the first embodiment, a marginally different method of converting the measured temperature into a frequency is used. In this arrangement, the algorithm followed by the computer 12 involves calculating the difference of the

measured temperature from a known fixed temperature and applying a corresponding frequency differential to adjust the scanning frequency of the scanner.

Moreover, this method involves taking the measured temperature, subtracting it

5   from a fixed reference temperature, and converting this difference into a frequency differential. This frequency differential can then be added to the known fixed frequency corresponding to the reference temperature to determine a new frequency, and the sample pulsed over a range of frequencies near to this new frequency. The net result is identical to that achieved by adopting the method

10 previously described in the present embodiment.

In accordance with a second specific embodiment, the sensing means comprises one or more RF antennas 17 attached to the NQR scanner 16. In one arrangement of the present embodiment, these antennas are narrow single turn coils of the same external dimension as the opening through which items are

15 passed into the NQR scanner for scanning purposes, and which are resonant at the NQR frequencies. These antennas do not transmit any signal but are arranged to only receive signals. The antennas are operated by the apparatus to monitor the RF emissions emanating from the item 14 to be scanned.

After being received on the single turn coil(s) the signals are amplified and sent to

20 the computer 12 via an analogue to digital converter (ADC). On the computer 12 the signals are filtered and then Fourier transformed to determine if there are any significant frequency peaks lying near to the NQR frequency of interest. If significant frequency peaks are found to exist above a prescribed threshold value, then the computer produces a signal indicating that the item is not suitable for

25 NQR detection. Accordingly, the apparatus is controlled to not scan the item and pass it straight through the NQR scanner 16 for alternative action, such as hand searching. Alternatively, if no significant frequency peaks are found, then the computer 12 permits the item to be moved into the scan volume of the NQR scanner 16 and be scanned. The decision making process programmed into the

30 computer 12 to provide for the detection of RF transmissions is shown in Fig.3.

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In accordance with a third specific embodiment, the apparatus comprises sensing means specifically in the form of one or more RF antennas belonging to a metal detector 18, which is also attached to the NQR scanner 16 so that these antennas are excited with pulses of RF energy which irradiate the scan item 14. In one
5   arrangement, these antennae are single turn coils having substantially the same dimensions as the main coil 15 within the NQR scanner 16.

The irradiation of a metallic object with RF energy induces eddy currents within the object, and this is used in the present embodiment to determine if any such objects are present.

10   Moreover, in the present embodiment, after a suitable period of dead time to allow for ring down of the coil, eddy currents induced within any metal objects contained within an item, induce a signal upon the RF antennas. This signal is amplified and converted into a digital signal via an ADC. This digital signal is then fed to the computer 12 where it is filtered and Fourier transformed into frequency space. If
15   significant peaks exist above a prescribed threshold level and close to the transmission frequency in the frequency spectrum, then the scan item 14 is flagged as having significant amounts of metal. The computer then signals an alarm or visual display indicating the presence of a significant amount of metal to the operator, which may indicate the presence of an object that is shielded by
20   metal. Fig.4 shows a flow chart of the decision making process programmed into the computer to provide for metal shielding detection.

In an alternative arrangement of the metal detector 18 described in the present embodiment, an induction balance system of metal detection is adopted, whereby two or more RF antennas of the metal detector 18 are attached to the NQR
25   scanner 16 so that at least one of these antennas or coils are continuously excited with RF energy to irradiate the scan item 14. It is necessary to use two or more coils to keep these coils in induction balance. That is, at least one coil transmits a signal and the remaining coils receive this signal but null it out either by suitable arrangement of the coils, or by applying a counteracting nulling signal to the
30   receiving coils.

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The present arrangement makes use of the phenomenon that the introduction of metal objects near to the coil disturbs the induction balance and results in a change in current required to maintain induction balance or simply a current is drawn through the receiving coil or coils. The apparatus provides for this current

5   to be converted into a digital signal via an ADC and then be sent to the computer 12. If this current lies above a prescribed threshold level, then the scan item 14 is flagged by the computer as having significant amounts of metal. The computer then signals an alarm or visual display to indicate the presence of a significant amount of metal to the operator, which may indicate the presence of an object

10 shielded by metal. The decision making process programmed into the computer to provide for metal shielding detection according to the induction balance method is shown in Fig.5.

In accordance with a fourth specific embodiment, the apparatus includes sensing means comprising one or more metal imagers 19 attached to the NQR scanner

15 16. These metal imagers are capable of creating an image of any metal objects within the scan item 14.

In the present embodiment, multiple coils are used to create an image of metallic items within the scan item. These multiple coils are arranged in a linear 1D, planar 2D or box shaped 3D array. In the 3D array, the coils are placed onto the sides of

20 a hollow rectangular box such that the scan item can be passed through the box and thus be imaged in 3D by the array. Each coil of the array is subjected to a transmit pulse which excites metal objects within the scan item and induces eddy currents.

After a period of dead time, to allow for the coil ringing to subside, the eddy

25 currents within the metal objects induce signals on the coil array. These signals are amplified and individually sent to an ADC included within the apparatus, where they are converted into digital signals. These signals are sent to the computer where they are Fourier transformed into frequency space. The resulting frequency signals for each coil are represented by the size of the frequency peak

30 and these peak intensities are combined by the computer to form a 2D or 3D metal image of the object. By appropriately scaling any image formed to real

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physical dimensions, it is possible to calculate what area or volume metal objects within the image occupy. If the area or volume occupied by a metal object exceeds a threshold value then the item is flagged by the computer as being possibly suspicious and sent for alternative processing, such as to be hand

5   searched or resolved by an X-ray scanner. The decision making process of the computer is shown in Fig.6.

In an alternative arrangement of the metal imagers 19 in the present embodiment, multiple receiving coils are used and are configured in an induction balance system. These multiple coils are arranged in a linear 1D, planar 2D or box shaped

10   3D array as before, whereby in the 3D array, the coils are placed onto the sides of a hollow rectangular box such that the scan item can be passed through the box and thus be imaged in 3D by the array. However in this arrangement, at least one coil is used to excite the system and the other coils are used to form the image. These other coils are in induction balance and do not receive the transmitted

15   signal, either because they are suitably arranged, or a counteracting current is applied to the receiving coils to keep them in a null state.

In the present arrangement, the transmitting coil of the array is subjected to a continuous RF signal. If a metal object comes close to the metal array the induction balance is broken and currents will flow through the receiving array of

20   coils. These currents are converted individually into a digital signal via an ADC and sent to the computer. The computer takes these individual currents and combines them to form a 2D or 3D metal image of the object.

By appropriately scaling any image formed to real physical dimensions of the scan item 14, it is possible to calculate what area or volume the image occupies. As

25   before, if the area or volume occupied by a metal object exceeds a threshold value, then the scan item 14 is flagged by the computer as being possibly suspicious and sent for alternative processing such as to be hand searched or resolved by an X-ray scanner. The decision making process followed by the computer is shown in Fig.7.

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The metal imagers 19 in the present embodiment are designed to generate metallic images by using long wavelength RF (1-100khz). In an alternative embodiment, a similar array of 1D, 2D or 3D coils is used to image metallic objects, but which operate in the microwave frequency region (high MHz-GHz).

5   The advantage of using microwaves is that the resolving power is much greater than the long wavelengths used in standard metal detectors, due to the much shorter wavelengths. Microwaves are also able to penetrate through waveguide like objects, whereas longer wavelength RF signals cannot. This makes microwaves able to distinguish loops of metal from solid, fully enclosed pieces of

10 metal.

In a further alternative of the present embodiment, a vertical and/or horizontal 1D array of coils is used to image metallic objects inside items such as bags. As the bag moves along a conveyor belt to the NQR scanner 16 through the 1D arrays of coils, a 2D or 3D image of the object can be built up by taking measurements

15 periodically over time as the bag moves through the 1D arrays, thus creating a 2D or 3D image of metal objects within the bag. This technique also allows the overall dimensions of the NQR scanner to be smaller than if a 2D or 3D array was required to image the metallic objects within the bag. This is advantageous in airports where space is at a premium.

20 Figure 10 shows a scan item 41 moving along a conveyor belt 40 into a 1D array of metal detecting coils 42 which are configured to sense the presence of metallic objects either through pulse induction or induction balance techniques, as described. The signals from the 1D arrays are sent to an analogue to digital converter (not shown) and then to the computer where the image is constructed

25 as the scan item moves through the array of 1D array of coils.

According to a fifth embodiment, the apparatus is interconnected with an X-ray machine for the purposes of locating metal objects. In this embodiment, the X-ray machine can be a standard AT type X-ray, a Multi View Tomography (MVT) type X-ray or a Computer Tomography (CT) type X-ray machine. It is well known that

30 X-ray machines are able to detect metal objects such as guns and knives. Hence,

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it is possible to use 2D or 3D X-ray images to identify metal objects, which could be potentially shielding explosives within scan items from NQR detection.

In the present embodiment, an NQR explosive detection scanner is placed next to an X-ray machine, where the X-ray machine is used to generate X-ray images of
5   an item passed through the machine, transfer these images to the NQR detection scanner, and the computer of the NQR scanner is operated to analyse the image for potential metal shielded objects. If any shielded objects are found the operator of the NQR scanner is notified, otherwise the item, such as a bag, passes through the machine unimpeded. In the present embodiment, the X-ray image is also used
10   to confirm the exact location of a metal object, after the computer has flagged the item as possibly containing a shielded object.

The decision making process followed by the apparatus in the present embodiment is shown in Figure 8.

In alternative arrangement of the present embodiment, X-ray and microwave
15   imaging is used in conjunction with each other to detect metal objects.

One of the main drawbacks of using the X-ray derived imaging to identify metallic shields is the inability of X-ray to successfully image aluminium foil. This is due to the small interaction between X-rays and the aluminium foil, unlike other metal targets. To help distinguish genuine aluminium metallic foil shields from other
20   metallic objects found in scanned items, the present arrangement involves subtracting the X-ray image of the item derived from the X-ray machine, from the 2D microwave image, to observe any aluminium foil type metallic shields that exist within the scan item. The microwave imager images all metallic objects whereas the X-ray machine images all metallic objects except aluminium foil. Thus the
25   difference between the two images will be objects formed or shielded by aluminium foil. The decision making process performed by the apparatus in this arrangement is shown in Figure 9.

In accordance with a sixth embodiment, the apparatus uses a further alternative for detecting metal objects involving use of the NQR scanner device itself for this

purpose. Using the NQR scanner device negates the need for adding extra units to the apparatus, which tends to increase the overall length of the apparatus. Limiting the length of the apparatus is important in space-constrained environments such as airports.

5   The NQR scanning device of the present embodiment has within it a tuned circuit comprising a coil and a bank of capacitors. The introduction of metal objects into the scan volume causes the tuned circuit to change its resonant frequency because the metal object lowers the inductance of the system. By adding capacitance, the circuit is then made to resonate at the correct resonant

10   frequency.

It has been discovered, pursuant to this invention, that if the resonant frequency and system Q are monitored as an item to be scanned is moved into the coil, then frequency and the Q profile can produce information about the shielded objects contained with the item.

15   Figure 11a shows the relative effect on Q and the frequency as an item is moved into the NQR scanning device. The item used in this example is a suitcase having a reinforced metallic loop around the inside of thereof. The frequency increases indicating that there has been a decrease in inductance and the Q factor has moved down indicating again a decrease in inductance.

20   As can be seen in Figure 11a, one of the main drawbacks of this method, however, is that most suitcase are reinforced with a metallic bag loop which runs right around the suitcase. Because of its size it causes the frequency and Q profiles to appear like there is a large metallic shielded object contained within the suitcase. However, obviously this is not the case. To overcome this problem it has

25   been found that the bag loops have typical frequency and Q profiles that can be readily identified and removed by curve fitting the profiles and subtracting out these profiles. What remains after this subtraction process gives an indication of whether there are shielded objects remaining in the suitcase.

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Accordingly, the computer of the NQR scanning device of the present embodiment is suitably programmed to be provided with appropriate suitcase curve fitting profiles and processing software to subtract out these profiles from scanned profile. The resultant objects are then correlated against an X-ray image
5   thereof to determine if a possible shielded object exists.

In one arrangement, this correlation is done manually by the operator or in another arrangement it is done automatically by image recognition software capable of performing the correlation and recognizing possible shielded objects against other benign metallic objects such as keys, coins, scissors etc.

10   Figure 11b shows the subtraction process. The bag loop signature in Figure 11a has been altered by placing a metal object within the suitcase and rescanning the object. This results in the dashed line, which denotes a summation of the suitcase signature and the metal object. Subtraction of the suitcase's signature reveals the presence of the metal object, which then is confirmed against an X-ray image.

15   In an alternative arrangement of the present embodiment for detecting metallic shields, the operating frequency of the NQR scanning device or metal detector is changed to specifically try to detect aluminium shields.

As previously mentioned, nearly all metal objects can be identified in an X-ray image because of their strong X-ray absorption characteristics. However
20   aluminium and in particular aluminium foil is an exception to this rule in that it generally cannot be imaged by an X-ray device because of the poor X-ray absorption characteristics. Hence there is a need for finding an alternative method of detecting aluminium shields.

In NQR scanning schemes, it has been found pursuant to the current invention
25   that significant amounts of aluminium foil severely affect the Q of the NQR apparatus over other types of metal. Hence large shifts in Q, coupled with the frequency scan as an item (such as a bag) to be scanned is moved into the coil, enable the possible identification of aluminium foil objects.

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Aluminium foil can also be identified by performing the measurements of the NQR scanning device or metal detector at two very different frequencies. It has been discovered, pursuant to the present invention, that aluminium foil cannot be easily detected below 100Hz due its thinness compared to the operating wavelength,

5   however other metals can still be detected. Consequently, the present arrangement of the embodiment involves measuring the bag at one higher frequency and subtracting the response, whether it be a metal image or one dimensional scan, from a scan at a frequency near 100Hz. Such a method should result in detection of aluminium shielded objects. Figure 12 shows the decision

10   making process for this embodiment.

In accordance with a seventh specific embodiment, as shown in Figure 2, the apparatus includes sensing means in the form of one or more lines of optical or infrared scanners 22, 23 positioned along a scanning conveyor 25 such that the length and height of a scan item 24 can be determined prior to scanning by the

15   NQR scanner device.

The sensors are positioned in straight vertical lines 23 to determine the height of the scan item 24 and straight horizontal lines 22 to determine the length of the scan item. If the scan item 24 exceeds the required height for the screening area 21 of the NQR scanner device, then it is bypassed around the scanning area 21

20   and not scanned. If the scan item's length is too long, then it is either bypassed around the scanning area 21 or it is scanned in two successive scans. The first scan covers approximately one half of the scan item and the second scan covers approximately the second half of the scan item. The results from the two scans are either analysed separately or added together to determine if an NQR

25   substance is present or not.

Determination of the length of the item enables the item to be scanned to be placed near the centre of the coil where inductive losses can, for some but not all, items be at a minimum. Minimising the inductive losses can result in the Q and frequency shifts being minimised, which results in the best possible opportunity for

30   detection of NQR signals because the Q is maintained at a high level.

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The eighth embodiment of the best mode is substantially identical to the first embodiment, except that in the eighth embodiment, an external temperature probe or probes 13 are connected to the NQR scanner which sense the external building temperature. Signals representative of the external building temperature

5   are in turn sent to the computer 12, which then instructs the transmitter unit 10 to send pulses to the coil 15 irradiating the scan item 14.

As in the first embodiment, if multiple probes are used then some mathematical combination is used to calculate the best temperature, such as the average. Temperatures are converted to frequencies via equations, such as equation 1, for

10 each separate substance. The scan item is irradiated at a range of frequencies close to the frequency produced by conversion of the temperature to a frequency. Pulses at these frequencies excite quadrupole nuclei of the particular NQR substance being detected within the item, if present, creating a small RF magnetic field that induces a small voltage on the coil 15 which is measured by the receiver

15 unit 11 and sent to the computer 12, resulting in a detection.

The external building temperature is measured in this embodiment because the NQR scanner may serve as an entry point to an important building such as a courthouse etc. Hence items brought into the building probably will reflect the external building temperature rather than the internal room temperature.

20 The ninth embodiment of the best mode is substantially identical to the first and eighth embodiments, except that in the present embodiment the temperature probe or probes 13 attached to the NQR scanner sense the external item temperature. Signals representative of the external item temperature are sent to the computer 12. The computer 12 then instructs the transmitter unit 10 to send

25 pulses to the coil 15 irradiating the scan item 14 at a range of frequencies which lie close to the frequency calculated from the measured temperature. If multiple probes are used then some mathematical combination is used to calculate the best temperature, such as the average. Temperatures are converted to frequencies via equations, such as equation 1, for each separate substance.

30 Pulses at these frequencies excite the NQR substance within the item creating a

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small RF magnetic field that induces a small voltage on the coil 15 which is measured by the receiver 11 and sent to the computer 12, resulting in a detection.

The external item temperature is measured in this embodiment because it may be found that the temperature of the scan item 14 is the most representative
5   temperature of the substance being scanned.

The tenth embodiment of the best mode is substantially identical to the preceding embodiments, except that in the fourth embodiment, the temperature probe or probes 13 on the NQR scanner sense the internal item temperature. Signals representative of the internal item temperature are sent to the computer 12. The
10   computer 12 instructs the transmitter 10 to send pulses to the coil 15 which irradiates the scan item 14 at a range of frequencies which lie close to the frequency calculated from the measured temperature. If multiple probes are used then some mathematical combination is used to calculate the best temperature, such as the average. Temperatures are converted to frequencies via equations,
15   such as equation 1, for each separate substance. Pulses at these frequencies excite the NQR substance within the item creating a small RF magnetic field that induces a small voltage on the coil 15 which is measured by the receiver 11 and sent to the computer 12, resulting in a detection.

The internal bag temperature is measured in this embodiment because it may be
20   found that the bag temperature is the most representative temperature of the substance being scanned. One method of determining the internal bag temperature is by using a microwave radiometer. Normal infrared wavelengths would be unable to penetrate through the outer layers of the bag, but microwaves having a longer wavelength can penetrate through the soft or hard plastic
25   coverings of most suitcases, resulting in a method for measuring the internal item without opening the scan item.

The eleventh embodiment of the best mode is substantially identical to the preceding embodiments, except that in the present embodiment, temperature probe or probes 13 attached to the NQR scanner sense one or more of room
30   temperature, external building temperature, external item temperature or internal

item temperature. Signals representative of these results are sent to the computer 12 which then instructs the transmitter 10 to send pulses to the coil 15 which irradiates the scan item 14 at a range of frequencies which lie close to the frequency calculated from some combination of the measured temperature or

5 temperatures. The temperature is converted to a frequency via equations such as equation 1 for each separate substance. Pulses at these frequencies excite the NQR substance within the item creating a small RF magnetic field that induces a small voltage on the coil 15 which is measured by the receiver 11 and sent to the computer 12, resulting in a detection.

10 In this embodiment it may be found that the best temperature to scan the bag is some mathematical combination of one or more of the temperatures being measured.

The twelfth embodiment of the best mode is substantially identical to the preceding embodiments, except that in the present embodiment a temperature

15 sensor or sensors 13 attached to the NQR scanner creates a thermal image or images of the item to be scanned. Signals representative of this image or images are sent to the computer 12 which then instructs the transmitter 10 to send pulses to the coil 15 that irradiates the scan item 14 at a range of frequencies which lie close the frequency calculated from some combination of one or more of the

20 pixellated temperatures measured.

Again temperatures are converted to frequencies via equations, such as equation 1, for each separate substance. Pulses at these frequencies excite the NQR substance within the item create a small RF magnetic field that induces a small voltage on the coil 15 which is measured by the receiver 11 and sent to the

25 computer 12, resulting in a detection.

In this embodiment it may be found that the best temperature to scan the object is some mathematical combination of one or more of the pixellated temperatures measured. This embodiment also allows the computer to check that the scanned object is not excessively hot or excessively cold. If it is found to have a

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substantially different temperature to the other surroundings the item is flagged to be checked manually by the operator.

The thirteenth embodiment of the best mode is substantially identical to the preceding embodiment, except that in the present embodiment, a temperature

5   sensor or sensors 13 and temperature probe or probes 13 are attached to the NQR scanner creating one or more thermal images and temperature probe measurements of the surroundings. Signals representative of these images and temperature probe measurements are sent to the computer 12 which then instructs the transmitter 10 to send pulses to the coil that irradiates the scan item

10   14 at a range of frequencies which lie close to the frequency that is calculated from some mathematical combination of one or more of the pixellated temperatures and temperature probe measurements.

As before, temperatures are converted to frequencies via equations such as equation 1 for each separate substance. Pulses at these frequencies excite the

15   NQR substance within the item creating a small RF magnetic field that induces a small voltage on the coil 15 which is measured by the receiver 11 and sent to the computer 12, resulting in a detection.

In this embodiment it may be found that the best temperature to scan the item is some mathematical combination of one or more of the pixellated temperatures

20   and the environmental surroundings. The embodiment also allows the computer to check that bag is not excessively hot or excessively cold. If found to have a substantially different temperature to the other surroundings the item is flagged to be checked manually by the operator.

The fourteenth embodiment of the best mode is substantially identical to the

25   preceding embodiments, except that in the present embodiment, one or more temperature 'tags' 20 are attached to the item 14 to be scanned. The tags 20 are small units and either display the temperature of the item to which they are attached, or the 'tag' emits an RF signal which is received by an aerial attached to the computer 12 to inform it of the item's temperature.

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Signals representative of the displayed temperature by way of the emitted RF signal are input into the computer 12, and the computer then instructs the transmitter to send pulses to the coil 15 that irradiates the scan item 14 at a range of frequencies which lie close to the frequency calculated from some

5   mathematical combination of one or more of the temperatures indicated by the tag or tags.

As before, temperatures are converted to frequencies via equations such as equation 1 for each separate substance. Pulses at these frequencies excite the NQR substance within the item setting a small RF magnetic field that induces a

10   small voltage on the coil 15 which is measured by the receiver 11 and sent to the computer 12, resulting in a detection.

In this embodiment it may be found that the best temperature to scan the bag is some mathematical combination of one or more of the temperatures indicated by the tags.

15   It should be appreciated that the scope of the invention is not limited to any particular one embodiment described herein, and that different combinations of features and modifications to the scanner device in order to accommodate the same that do not depart from the spirit of the invention fall within its scope.